SERIAL NO.
Translation No. 309

No. of Pages 18

296/900

Date: December 19, 1935

WAR DEPARTMENT
AIR CORPS
MATERIEL DIVISION
DAYTON, OHIO

TRANSLATION
No. 309

COMPILATION OF DETAILS RELATIVE TO SMOOTH SHEET METAL MONOCOQUE CONSTRUCTIONS IN FOREIGN COUNTRIES

by

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From - Luftfahrtforschung, No. 8
February 6, 1935
Pages 235-240

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COMPILATION OF DETAILS RELATIVE TO SMOOTH SHEET METAL MONOCOQUE CONSTRUCTIONS IN FOREIGN COUNTRIES

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1. General Discussion of Smooth Sheet Metal Monocoque Fuselages

The monocoque wood fuselage may be regarded as a forerunner of the monocoque metal fuselage. As early as the war this type of construction had been employed, though infrequently, by the Germans as well as the French. Figure 1 shows the interior of such a monocoque wood fuselage.

After the war, in a desultory development of airplane construction, application of this structural type remained limited to few specific designs, in which the constructor by particularly smooth shaping endeavored to increase the speed. Only more recently a change occurred beginning with the Lockheed "Vega". After a longer interval this airplane again was constructed as monocoque wood type in production manufacturing.

The transition to the monocoque construction in production manufacturing should be regarded as a logical step in the progress of

structural types. Two essential assumptions for the monocoque construction are met; namely:

1. Certain standards are being developed more and more in commercial as well as military aircraft as to fuselage dimensions and shape, in which, doubtless for production reasons, the introduction of the monocoque fuselage is favored.

2. Further standardization in aeronautics also enables the production of greater numbers. In this way the monocoque, of high cost in special constructions, can compete with other structural types in the production cost.

Furthermore with the introduction of the monocoque type in general and the smooth sheet metal type in particular, the following advantages are combined:

a) Through differences of form the stressed fuselage skin offers special advantages of space. In the fuselage interior cross bracings can be limited to a minimum, so that storage space is secured, practically free from interfering cross bracings.

b) In the endeavor to increase the speed by improved aerodynamic design, application of the smooth sheet metal skin is a welcome remedy. In particular fuselage-wing and tail surface jointures of favorable aerodynamic design can be developed (Figs. 2 and 3). At the same time a smooth outer skin, constant as to form, is obtainable, advantageous to surface resistance.

c) As the full structural height is always available as girder height, the monocoque construction enables good utilization of material.

For the present it seems that in the case of small fuselages the trussed framework type of construction still is superior, but for large fuselages the monocoque type should be advantageous. As a rule the weight of a monocoque construction is estimated at double the weight of the skin.

d) Because of its high strength, a monocoque fuselage generally is less inclined to vibration.

e) In the case of metal covering constant inspection of vital parts is simplified, as the outer skin is used for the transmission of force and the number of highly stressed and concealed joints is much smaller than in the case of trussed framework constructions. Also in loss of single sheet sections the reliability of operation is not endangered. Reference shall be made briefly as to the general advantages of metal constructions such as resistance to weather conditions, durability, and service. The high production cost of monocoques, which often is cited as disadvantageous, can further be reduced by skillful construction and improvement of production methods.

2. Classification of Monocoque Fuselages

The monocoque fuselage is designed to carry either the full load or part of the load in the curved outer skin. Fuselages with complete framework, to which an outer skin is attached for covering purposes, as well as other complete framework types, are eliminated from this discussion. According to the structural type, three principal groups of monocoque fuselage types can be differentiated:

1. Monocoque fuselage with transverse and longitudinal stiffening.
2. Monocoque fuselage with transverse stiffening.
(3. Monocoque fuselage without stiffening).

The monocoque fuselage with transverse and longitudinal stiffening is characterized by only local stiffening of the external skin. For this reason the skin is not resistant to shear and compression at all points, but localized buckling is likely to occur at sufficiently high loads. Stiffening of the skin may be accomplished in either of the following ways:

a) Directly by longitudinal stringers alone; in this case the outer flange of the longitudinal stiffener is connected to the skin, while the inner flange of the longitudinal stiffener rests on the transverse bulkhead (Fig. 4).

b) Directly by longitudinal stringers and bulkheads; in this case the outer flange of the transverse bulkhead also is fastened directly to the skin (Fig. 5). As a special case of this structural type the Northrop fuselage, in which longitudinal stiffening is obtained by bending up a lip of the covering (Fig. 6), should be listed. Frequently also in the highly rounded corners of bulkheads, there are reenforced, continuous longitudinal stringers, which may be regarded as spar-like stiffening (Fig. 7). A type of transition to the monocoque fuselage with only transverse stiffening is that in which longitudinal stiffening is applied only to the slightly curved, thin side walls, whereas the more highly curved upper and lower sides, by use of greater sheet thicknesses, are stiffened only by bulkheads (application as yet unusual).

In the monocoque fuselage with transverse stiffening (Fig. 8), only with the aid of bulkheads, a skin is obtained fully resistant to shear and compression, and buckling should not occur. As far as known, this

structural type is used at present only in the American transport airplane, the Vultee V-IA.

(In the case of material with sufficiently low specific weight and adequately high E modulus, a monocoque fuselage without any stiffening whatsoever is conceivable. The material problem in this connection still requires solution).

3. Development of Monocoque Elements

a) Bulkheads.

Nelson[1)] has suggested about half of a fuselage diameter for the spacing of bulkheads. It seems statically confirmed in the case where the bulkhead is riveted to the outer skin, that a better stiffening of the skin in the smallest cross section, with reference to torsional stress, is obtainable. Also because of the introduction of localized forces from tail surfaces and skid, close spacing of bulkheads at the fuselage end is desirable. On the other hand Miller[2)] feels assured of advantages in production, in uniform bulkhead spacing, as the skin can be attached in equally wide, circular strips. Which of these two general methods is the better cannot be determined at present, yet in consideration of a minimum expenditure of weight it is essential to balance spacing of bulkheads, longitudinal stringers, and thickness of the skin with each other. Selection of bulkhead spacing generally remains optional for the constructor only in the fuselage portion behind the cabin, or seats, whereas in front the position of bulkheads is determined largely by doors, windows, cut-outs for seats and attachments. In the case of monocoque fuselages developed, either the

Nelson or the Miller principle is followed in the rear portion of the fuselage. Bulkhead spacing frequently selected runs from 250 to 500 mm.

Except for spinning circular bulkheads are aerodynamically favorable. At the same time the lowest weight of the skin is obtainable, as the circle has the smallest circumference with reference to the surface circumscribed. But utilization of interior space is not particularly advantageous in the case of passenger airplanes. For better utilization of space, the elliptical section is almost equally advantageous aerodynamically. Miller suggests that the bulkhead sections be formed with several standard radii, thus reducing production cost by saving of patterns.

In the constructions developed, three principal bulkhead types can be differentiated:

a) Form bulkheads.

b) Principal bulkheads.

c) Stiffened principal bulkheads.

Form or auxiliary bulkheads generally are used for better maintenance of the outer fuselage form. They are relatively weak and can be scarcely considered as bulkheads. For form bulkheads, generally smaller simple thin-walled sections are used. (Compare Figs. 9a, b.)

Principal bulkheads are used for maintenance of form and as static structural members for the reception of principal forces. Profile forms, as frequently found in foreign monocoque fuselage constructions, are shown in Figure 9 (profiles a to f). Profiles d, e, f were developed by the Hall Aluminum Aircraft Corporation in Buffalo. The bulbous section (f) has the advantage of great strength, but is unfavorable for inspection of corrosion. An example of Hall profiles is shown in Figure 10.

For taking of highly localized loads reenforced principal bulkheads are used; as such fireproof bulkheads, landing gear bulkheads, wing attachment bulkheads, and terminal bulkheads are always developed. They are developed as closed or box sections (compare Figs. 9 g and h, Fig. 11).

b) Longitudinal Stringers

According to the type of joining of bulkheads and longitudinal stringers, the following three types can be recognized:

1. Longitudinal stringers, continuous, supported on bulkheads; bulkhead continuous (Fig. 12).

2. Longitudinal stringers intercostal; bulkhead continuous (Fig.13).

3. Longitudinal stringers continuous; bulkhead cut-out. (Figs. 14 and 15).

Intercostal longitudinal stringers are disadvantageous statically; therefore this type is seldom used. Profile forms, as frequently used for longitudinal connection, are shown in Fig. 9 i to t. As to which is the most advantageous profile form, cannot be determined at present. The closed profile forms according to i and k show a great resistance to buckling and bending, but on the other hand require a second rivet seam. Usually maximum spacing between two longitudinal stiffeners is equal to 250 to 300 times the thickness of the skin, and the width of the skin, which works with the stiffener, is equal to 40 times the thickness of the skin; this estimate should apply to slightly curved and flat sheets. An example of the T-profile in longitudinal connection is shown in Figure 16.

c) Skin

The skin is attached either in long strips to the fuselage (Fig. 17), or in single sheets corresponding to the bulkhead spacing. Whether the one or the other method is used, depends principally on the fuselage construction and production method. In the case of careful aerodynamic design, the varying curvature of the metal skin almost always exists. In such cases frequently a stronger lower section of the metal skin is used, in order to modify the required preliminary forming. The use of smaller covering sheets also is advantageous in the repair of damage, as damaged skin portions can easily be removed by boring out of rivets, and replaced by new parts.

According to Nelson for monocoque fuselages with longitudinal and transverse stiffeners, the usual skin thickness is between 0.5 and 1.3 mm. when using aluminum-alloy sheets. For monocoque fuselages with only transverse stiffening, it naturally would be correspondingly greater; thus, for the Vultee V-IA (Airplane Development Corp.), it is developed at a thickness of 1.3 to 2.3 mm. At some locations in the fuselage the thickness of the skin is determined by the required strength for handling. The strength of the skin depends on the proportion of the radius of curve to thickness of the skin; as practically attained Nelson gives the value of 1200 for this relation.

The single metal sheets are riveted on the bulkheads and longitudinal stringers, or only on the latter, when the longitudinal connections rest on the bulkheads.

d) Joints

For sheet thicknesses between 0.5 and 1.4 mm. Nelson recommends